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Birefringence induced by pp-wave modes in an electromagnetically active dynamic aether

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Abstract In the framework of the Einstein–Maxwell-aether theory we study the birefringence effect, which can occur in the pp-wave symmetric dynamic aether. The dynamic aether is considered to be a latently birefringent quasi-medium, which displays this hidden property if and only if the aether motion is non-uniform, i.e., when the aether flow is characterized by the non-vanishing expansion, shear, vorticity or acceleration. In accordance with the dynamo-optical scheme of description of the interaction between electromagnetic waves and the dynamic aether, we shall model the susceptibility tensors by the terms linear in the covariant derivative of the aether velocity four-vector. When the pp-wave modes appear in the dynamic aether, we deal with a gravitationally induced degeneracy removal with respect to hidden susceptibility parameters. As a consequence, the phase velocities of electromagnetic waves possessing orthogonal polarizations do not coincide, thus displaying the birefringence effect. Two electromagnetic field configurations are studied in detail: longitudinal and transversal with respect to the aether pp-wave front. For both cases the solutions are found, which reveal anomalies in the electromagnetic response on the action of the pp-wave aether mode.

1 Introduction

The effect of birefringence is well documented in the electrodynamics of continuous media [1–5]. This effect reveals itself, in particular, when the electromagnetic waves possessing two orthogonal polarizations are forced to move with different phase velocities, thus being converted to the so-called ordinary and extraordinary waves. The medium behaves as the birefringent one, when the electric and magnetic susceptibility tensors of the medium are anisotropic, i.e., when these tensors possess non-coinciding eigen-values (the medium is called bi-axial, if all three eigen-values are different, and uni-axial, when only two of them coincide). The birefringent property of the medium can be the intrinsic one (e.g., in the spatially anisotropic crystals [6], in moving uni-axial media [7]), or they can be induced by external influences (e.g., by an external electric field [4,5], a magnetic field [8,9], stresses, anisotropic heating, etc., [6]). When we deal with electromagnetic waves propagating under the influence of the gravitational field, various versions of the gravitation theory predict different results. For instance, the pre-metric axiomatic theory guarantees (see, e.g., [10]) that there is no intrinsic birefringence. Similarly, the minimal Einstein version of the theory of gravity excludes birefringence. However, in the framework of the modified theories of gravity the effect of birefringence was predicted by many authors. For instance, the nonminimal Einstein–Maxwell theory admits the birefringence effect since the coupling of photons to the curvature makes the nonminimal susceptibility tensor anisotropic (see, e.g., [11–13]). Violation of the Lorentz invariance of the model [14–18], a torsion nonminimally coupled to photons [19], interactions with strings [20], also can be the origin of the birefringence effect. These predictions have attracted the attention to the problem of cosmic birefringence and its observations [21–25].

Our goal is to study the birefringence induced by the dynamic aether. We assume that when the motion of the aether is uniform, the aether is not birefringent, i.e., the effect we search for is hidden. In other words, when the motion of the aether is uniform, the test electromagnetic waves do not display the dependence of the phase on the polarization; however, when the aether flow is characterized by non-vanishing acceleration, shear, rotation or expansion, we deal with the so-called degeneracy removal with respect to the hidden parameters in analogy with effects described in [26]. The idea of a mathematical description of this degeneracy removal was disclosed in Ref. [1]; there the corresponding term *dynamo-optical phenomena* was introduced. In order

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